Hybrid Imaging: SPECT/CT

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COI

• No specific COI
• Dr. Schuster involved in Emory University commercial grants
  – Blind reader Amyvid Post-Market Study
• American Imaging Management Specialty Physician Advisory Panel
Talks can be found at radiology.emory.edu
Department of Radiology and Imaging Sciences

Moving Forward

As we embark on a new strategic plan (2013 - 2017), we face a more challenging health care and economic environment with added uncertainties and hurdles to overcome. Yet we are well prepared to take on this task by building on our record of progress, and critically examining both our successes and vulnerabilities. Through a series of monthly strategic planning meetings, focused retreats, and input from department members and field experts (including The Advisory Board), we have examined our mission and vision and identified priorities for the new plan.

Read more in the April Rad Report

New Grant

Tagging Medical Data Streams with Patient Photographs to Decrease Patient Misidentification Errors

Principal Investigators: Sriki Trivedi, MD, JD
Clinical Divisions - Nuclear Medicine & Molecular Imaging

The faculty of the Emory Division of Nuclear Medicine & Molecular Imaging offers the highest quality patient care, incorporating the latest knowledge, innovation and equipment. Nuclear Medicine not only uses the most advanced methods, but also helps set the bar for the field. All of our physicians are board certified in nuclear medicine, and some are double-boarded in other fields, particularly Radiology; many have national and international reputations in their fields.

Equipment includes PET/CT and SPECT/CT scanners at Emory University Hospital (Clifton campus) and Emory University Hospital Midtown. We offer a wide variety of specialized nuclear medicine therapies including that for thyroid cancer, bone cancer pain palliation, lymphoma, neuroendocrine tumors and Y-90 liver therapy in cooperation with Interventional Radiology. Research devices at our disposal include a high-resolution brain PET scanner, micro-PET/CT for animal research, and a research cyclotron. A full range of nuclear medicine and PET/CT services are also provided at Grady Memorial Hospital and the Atlanta VA Medical Center. The Division is integrally involved in research as well as close collaboration with colleagues in Radiology, Cardiology and the Emory Winship Cancer Institute. Our faculty are principal investigators and co-investigators on many research grants including those sponsored by the NIH.

- David M. Schuster, MD
  Associate Professor of Radiology and Imaging Sciences
  Director, Division of Nuclear Medicine and Molecular Imaging

Recent Conferences
Prostate Cancer With Rising PSA

Cystoprostatectomy: urinary drainage bag

But also foci of abnormal uptake near right SI joint, lower LS spine, and elsewhere

Degenerative or Metastatic?

Can SPECT-CT help?
L-Spine – Degenerative with Confidence
Right SI Region – Metastasis with Confidence
Added Confidence from CT Alone
What is SPECT/CT?

- Hybrid Imaging
- Combines functional imaging with anatomic imaging
- This talk will concentrate on clinical aspects of SPECT-CT
  - Many similar principles apply to PET-CT
Why Hybrid Imaging?

• Advantages
  - Attenuation correction
  - Increased sensitivity and specificity
  - Anatomic localization
  - Improved confidence in interpretation
  - Shortened acquisition time
SPECT/CT

  - 40 patient retrospective; 50 lesions
  - Planar and SPECT: 61% lesions equivocal
  - SPECT/CT: 8% equivocal
  - Kappa: Planar .43; SPECT .56; SPECT-CT .87
  - SPECT/CT resulted in significant reduction in equivocal reports
SPECT/CT Protocol

- SPECT and CT not at same time
- Free breathing
  - CT images acquired much more quickly than SPECT images.
    - Respiratory Gating
- Potential to use oral contrast
- Potential to use IV Contrast
- Radiation exposure from CT
  - But generally lower dose CT
  - $\frac{1}{2}$ dose or less
Potential Sources of Error Impacting Clinical Reading

- Similar to PET/CT
  - SPECT-CT more forgiving
    - AC values not as much changed
    - PET more tissue to attenuate due to both photons

- Misregistration between SPECT and CT datasets

- Metal artifact
- Table sagging
- Patient motion
- Truncation artifact
- Beam hardening artifact
SPECT/CT Considerations

SPECT/CT Misalignment

• SPECT and CT must be precisely aligned
• Misalignment
  - Hampers interpretation
  - Hampers attenuation correction
• Registration software can be helpful
Similar to PET/CT
Critical to Have Non-AC Available

Misregistration due to motion between CT and PET

Asymmetry on AC images but not on non-AC images
Registration Especially Important with Cardiac SPECT/CT

SPECT/CT Misalignment
• Pt moved between SPECT and CT

Manual Registration
• Used to correct for mismatch
• Careful attenuation to detail
Issues Similar to Cardiac PET-CT

Apparent lateral wall ischemia
Image Re-registration (Automated vs. Manual)
“Ischemia” Resolves
Metal Artifacts

- CT artifacts become SPECT artifacts in the attenuation corrected images.
- When artifacts cannot be avoided, the attenuation corrected images must be carefully evaluated.
Similar to PET/CT

with CT-AC
without AC
SPECT/CT Diaphragm Motion Artifact

Motion of the Diaphragm
- Heavy rapid breathing can make the position of the diaphragm vary in consecutive CT slices.
- Each axial slice can look fine but coronal images reveal problems...

Siemens Symbia T6
Similar Artifact on PET/CT
SPECT/CT Considerations

CT Scan Truncation

- Truncation introduces streak artifacts in images
- Degrades the accuracy of attenuation correction
Siemens Symbia T6 at Emory University Hospital

\[^{123}\text{I} \text{ MIBG SPECT/CT}\]
Utility of SPECT/CT

- Bone
- Endocrine
- Neuroendocrine
- Prostate
- Parathyroid imaging
- Infection
- Neurology

- Coronary artery disease
- Pulmonary embolism
- Splenosis
- Radionuclide therapy
- Many others waiting to be described….

Good review:
Bones

• SPECT/CT
  - More accurate localization
  - Evaluation of morphological changes on the CT
  - Localizing bone infection or joint inflammation
  - Correlation scintigraphic findings with anatomic images for better clarification of indeterminate bone lesions
  - Provides higher diagnostic confidence
Bones

  - Good review

  - 76 patients nonspecific findings
  - Added clinical value in 89%
Back Pain

- 18 year old with back pain
- Plain films equivocal
- Bone scan ordered
Abnormal uptake lower lumbar spine
Confident diagnosis of pars defects
Missed on original outside MRI but seen upon review
911 Call

Planar only can be confusing
SPECT-CTDifferentiates Trauma from Degenerative/Post-op

With confidence we can say:
Degenerative at L2-3.

Fusion cage uptake at L4-5.

Endplate fractures L5 inferiorly and S1 superiorly with hematoma.
Fracture Therapy Planning
What is Causing the Pain?

Difficult with CT (or MR) alone
Fracture Therapy Planning

What is Causing the Pain?

SPECT-CT shows intense uptake at minimal compression at L1 and only mild uptake at superior endplate of moderate-severe L2 compression.
And Also That Posterior Elements Not Involved
Back Pain and Rising PSA to 9.8 Post-Prostatectomy
Suspicious Lesion in Sacrum
Also Degenerative Uptake
Known Ovarian Cancer

- Question bony metastases

Bone scan ordered
Hawkeye SPECT/CT to localize extraosseous uptake...
Endocrine


- 71 thyroid patients
  - SPECT/CT additional value over planar in 57%
    - Lymph node metastases versus remnant thyroid tissue
    - Lung versus mediastinal metastases
    - Skeleton
  - Impact on patient management
Thyroid Cancer

- Patient treated for thyroid cancer post surgery with 100 mCi
- Lymph nodes negative
- No pre-treatment scan
- 7-10 day post therapy scan
SPECT-CT Performed

Uptake in left parapelvic renal cyst. Obstruction excluded on ultrasound.

Uptake has been described in renal and hepatic cysts and many other locations.

Hypothyroidism

4 hours lateral

24 hours

No thyroid bed uptake and low 24 hour uptake; globular activity base of tongue
SPECT-CT Confirms Lingual Thyroid
Parathyroid Imaging

- SPECT/CT based scans identify more tumors than planar or SPECT alone.
- Higher diagnostic performance and/or confidence in general
  - Enable minimally invasive resection
- Demonstrated in a number of papers
  - *Wimmer et al. Langenbecks Arch Surg* 2008;393:687
    - Sensitivity 87%, specificity 97% fusion with CT
    - Sensitivity 50%, specificity 92% SPECT alone
  - *Serra et. al. Radiol Med* 2006;111:999–1008
    - SPECT/CT localized 100% positive lesions vs 61% for SPECT only
Fusion Imaging

  - 110 patients with primary hyperparathyroidism
  - Different combination of planar, SPECT, SPECT-CT
    - Early SPECT-CT with any delayed imaging best combination
      - 72-73% sensitivity; >99% specificity; 86.3-90.7% PPV
  - First SPECT-CT CPT code for parathyroid adenoma in 2013: 78072
Hyperparathyroidism
Hyperparathyroidism

Right inferior within thyroid. Proven to be thyroid adenoma.
Hyperparathyroidism

Subtle uptake left inferior tracheoesophageal groove is the real parathyroid adenoma. Corresponds to soft tissue on CT.
Hyperparathyroidism

SPECT-CT really shines with ectopic adenomas...
Hyperparathyroidism
Hyperparathyroidism

Pinpoints
ectopic
Neuroendocrine

• Carcinoid
• Pheochromocytoma
• Paraganglioma
• MIBG imaging
• SPECT/CT
  - Increases accuracy for detection of disease
  - Degree and distribution of tracer uptake allows for assessment of potential therapies
Neuroendocrine

  - 72 patients
    - In-111-DTPA-pentetreotid (Octreotide)
  - SPECT/CT improved localization of SPECT detected tumors in 23/44 positive cases
  - Affected clinical management in 10 patients

  - 81 patients
    - In-111-DTPA-pentetreotid (Octreotide)
  - ROC analysis SPECT/CT better than SPECT
  - SPECT/CT correctly localized 94.7% vs SPECT 45.6%
Carcinoid

- 53 year old female
- History carcinoid
- Recent abdominal CT demonstrates multiple hepatic lesions consistent with metastases but otherwise negative
Largest liver met confirmed with OctreoScan
Lymph node met confirmed on OctreoScan but overlooked on CT
Another Patient...

- 62-year-old male diarrhea and flushing with known hepatic metastatic carcinoid without identification of primary lesion.

- Underwent right hemihepatectomy and multiple intraoperative RF ablations.

- Now symptom free.

- Post operative MR showed persistent hepatic lesions but no other foci.
$^{111}$Indium Octreotide showed the more active liver lesions but also 2 foci in RLQ
Retrospectively fused to MR: identified retroperitoneal node and primary ilial lesion

Changed Management
Software Fusion

• Though more labor intensive

• Software fusion does a great job

• Especially if you do not have the hardware or the hardware has not been invented yet
Fused Octreoscan SPECT-MR of Insulinoma
I-123 MIBG for Suspected Pheochromocytoma
Pheochromocytoma

Right adrenal mass seen well.

But also other lesion detected with SPECT.
Pheochromocytoma

Localizes precisely as small node behind right renal vein unsuspected on prior CT scan.

And differentiated from nearby renal activity.
NeuroImaging

• In the brain it is thought that it is easier to compare a prior obtained CT or MR to SPECT
  - Structures are relatively fixed
  - SPECT-CT or software fusion has added value
    • Structures are also very close to each other
    • There may be changes even over a short time

• Sulkin et al. Clin Radiol 2008;63:289
  - SPECT/CT cerebral perfusion
  - 25% low dose CT had abnormalities
  - 15% discordance with previous imaging
Dementia

- 32-year-old married white male
  - 8-month history of progressive cognitive loss forgetfulness, misplacing things, good mood, word finding difficulty

- MRI “negative”; PET/CT ordered
Diagnosis of FTD can be made with PET alone, but having CT showing subtle frontal atrophy in a 35 year old adds to confidence.

Similar principles for SPECT/CT such as DATscan and other radiotracers
Arachnoid Cyst?

- 32 year old female with headaches
- Communicating or noncommunicating arachnoid cyst?
SPECT/CT has added value over planar to confirm communication.
Cardiac

• Nuclear Cardiology
  - SPECT
    - Evaluate myocardial ischemia and functional significance of coronary artery disease
    - SPECT/CT high resolution, high count rate, low noise AC maps
    - Can be combined with calcium score and/or CTCA

• Nakaura et al AJR Am J Roentgenol 2005;185:1554

Cardiac
Cardiac
Cardiac

Presence or absence of calcium can influence reading confidence depending on clinical scenario.
Cardiac

More advanced possibilities
Radionuclide Therapy

- **SPECT/CT**
  - Useful in pre and post therapy Y90 imaging
    - pre-therapy assessment with MAA and post therapy imaging to demonstrate Y-90 microsphere uptake by tumor and extrahepatic uptake
  - May aid in the future for more precise dosimetry
Radionuclide Therapy

  - SPECT/CT increases sensitivity and specificity of Tc99m SPECT for detecting extrahepatic arterial shunting

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<tr>
<td>Planar</td>
<td>25%</td>
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<td>SPECT/CT</td>
<td>100%</td>
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Radionuclide Therapy
Radionuclide Therapy

SPECT-CT shows uptake in stomach on MAA
Radionuclide Therapy

More precisely map Y-90 deposition on Bremsstrahlung SPECT/CT compared with planar images
Radionuclide Therapy

Fused FDG and Bremsstrahlung confirms $^{90}$Y coverage of tumor
Infection

- WBC, Gallium, new infection tracers
  - 17 studies in 16 patients
  - Compared with "side-by-side" SPECT-CT
    - Fused SPECT/CT images yielded "added value" for anatomical localization in 65%, diagnostic confidence in 71%, altered interpretations in 47% of cases
  - SPECT/CT changed interpretation in 10/19 suspected sites in diabetic foot
Soft Tissue vs Osteomyelitis
Splenosis

• Positive papers on advantages

  - All 20 equivocal lesions correctly classified.
  - 3 additional lesions overlooked by CT or MRI detected

  - Localization of splenosis using 99mTc-damaged red blood cell SPECT/CT and intraoperative gamma probe measurements
ProstaScint

• Fusion with CT or MR has been reported to improve accuracy
  - Anatomic localization improves specificity
  - Makes RBC imaging "superfluous"
  - Synergistic value
  - Improved AC and resolution recovery

• Schettino CJ et al. AJR Am J Roentgenol. 2004;183:519
• Sodee DB et al. Semin Nucl Med 2007;37:17
ProstaScint

Addition of CT helps differentiate blood pool from nodal involvement
Sentinel Lymph Node Lymphoscintigraphy

- SPECT/CT
  - Improves accuracy of sentinel lymph node localization at various sites
    - Breast, neck, chest, pelvis
  - Allows detection of nodal disease not seen on planar imaging especially in obese
  - Melanoma: clear advantage in 35% patients
  - Gallowitsch et al. Nuklearmedizin. 2007;46:252
    - SPECT/CT more accurate characterization size, depth and anatomical location
Pulmonary Embolism

• VQ and the addition of SPECT has been demonstrated to have added value even in the era of MDCT

• How about VQ SPECT-CT?
  - May help clarify cause of perfusion defects
  - Novel advanced techniques to improve accuracy

• Early work show promise:
  - Suga et al. AJR Am J Roentgenol 2007;189:455
Many Other Possibilities

- GI bleeding studies for better localization

- Meckel’s Scan

- Breast scintimammography
GI Bleed Localized to Cecum
Incidentaloma
(Similar to PET/CT)

  - Even with very low dose CT on cardiac SPECT
  - 10.5% of patients potentially significant findings

  - 64 slice low dose cardiac SPECT-CT
  - 33.7% relevant findings
Incidental Findings

6 cm AAA; Horseshoe kidney in patient with lung cancer
Incidental Findings

New right prominent collecting system and FDG retention on PET
Incidental Findings

Stone in ureter
Conclusion

• Fusion imaging with SPECT/CT
  - Added value similar to PET/CT
  - Increases accuracy
  - Increases precise localization
  - Increases confidence

• Can help take the “unclear” out of “nuclear”

• Utility limited only by our imaginations

• Protocols and radiation issues must be optimized
The End